

Ionized gas and sources of its ionization in the Irr galaxy IC 10

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Abstract. IC 10 is the nearest starburst irregular galaxy remarkable for its anomalously high number of WR stars. We report the results of an analysis of the emission spectra of HII-regions ionized by star clusters and WR stars based on observations made with the 6-m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences using MPFS field spectrograph and SCORPIO focal reducer operating in the slit spectrograph mode. We determine the masses and ages of ionizing star clusters in the violent star-forming region of the galaxy in terms of the new evolutionary models of emission-line spectra of HII-regions developed by [6]. We estimate the amount of stars needed to ionize the gas in the brightest HII-region HL 111 and report new determinations of oxygen abundance in HII regions.

1 Introduction

IC10 is the nearest dwarf Irr starburst galaxy; its H_α image appears as a giant complex of multiple shells and supershells with sizes ranging from 50 to 500-800 pc (see Fig. 1). About sixty star clusters have been found in this galaxy ([3], [10], [12]). The stellar population of the galaxy and its anomalously high space density of WR stars (similar to that in massive spiral galaxies) are indicative of a short recent starburst affecting the bulk of the galaxy.

2 Observations

We observed the galaxy with the 6-m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences using the MPFS field spectrograph and SCORPIO focal reducer operating in the Long Slit Spectrograph mode. Figure 1 shows the locations of MPFS fields (named according to the corresponding central WR star) and those of long-slit spectrograms (named according to their position angle). Below we summarize the main results of these observations, which we reported in detail in our papers ([1], [4]).

3 Results

We analyze the emission spectra of the ionized gas in the HII-regions observed, including the region of violent star formation (see Fig.1). Figure 1 shows clusters from the

lists of [3], [12] and [10] (circles indicate objects from the former two lists and crosses, those from the latter list). HII-regions are labelled by their names according to the [2] catalog.

Earlier ([4]) we found that diagnostic diagrams of the relative line intensities from our observations with Long-Slit spectrograph agree poorly with the photoionization models available for the gas metallicity $Z = 0.2Z_\odot$ in IC10.

In this work we compare our observations with new evolutionary synthesis models of [6] and find the diagnostic diagrams for these models to agree well with our observations (see Fig. 2).

We use the evolutionary models of [6] to show in Fig. 3 the dependencies of the observed relative line intensities and H_β -luminosity on cluster age for different cluster masses, and also the dependence of ionization parameter on the $[SII]6717/H_\alpha$ line intensity ratio for different ages and masses. We use these dependencies to estimate the parameters of the clusters that are the most likely sources of ionization for the observed HII-regions.

Table 1 gives the masses, ages, and ionization parameters of the clusters (named according to [12]) that are most probable sources of ionization for the corresponding HII-regions. The ages of ionizing clusters in IC 10 are shown to range from 2.5 to 5 Myr, and their masses, from 0.2×10^5 to $10^5 M_\odot$.

We estimate the amount of O5V stars needed to ionize the gas in the HL111 nebula based on the measured H_β -luminosity and the photon UV-luminosity of O5V star $Q_0 = 1.6 \times 10^{49}$ photons/s for the metallicity of $Z = 0.2Z_\odot$ from [11]. We find that about a hundred of O5V stars are needed to ionize HL111 - the brightest HII-region in IC10.

We use the empirical method of [8] to determine the oxygen abundance in the HII regions observed. The results are presented in Table 2.

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Table 1. Parameters of HII-regions and their ionizing clusters.

HII-region	Cluster	N_e, cm^{-3}	$L(\text{H}\beta), 10^{39} \text{ erg/s}$	Age, Myr	Mass, $10^5 M_\odot$	$\log(U)$
HL111	T54	70	1.3	$3.5 \div 4.0$	$1.0 \div 1.5$	-2.5
HL106	T50, T53	200	1.0	$4.0 \div 4.5$	≥ 1.0	-3.0
HL50	T32	30	-	$3.4 \div 3.6$ or $2.5 \div 3.0$	$1.5 \div 2.0$ or $0.4 \div 1.0$	-2.47
HL111a,b, HL100	T52	200	-	$3.8 \div 4.5$	$0.2 \div 0.6$	-3.27
HL46-48	T24, T27	-	-	$4.0 \div 5.0$	$0.2 \div 0.4$	-3.6
HL89	T47	200	-	> 3	≥ 0.2	-

Fig. 1. Location of slit spectrograms and MPFS fields on the $\text{H}\alpha$ -images of IC 10: the entire galaxy (left) and the bright region of current star formation (right). The asterisks denote the spectroscopically confirmed WR stars from [9] and from [7]. The circles show the clusters from [3] and from [12] and the crosses, the centers of clusters from [10]. The names of HII-regions listed in Table 1 and Table 2 are given according to [2].

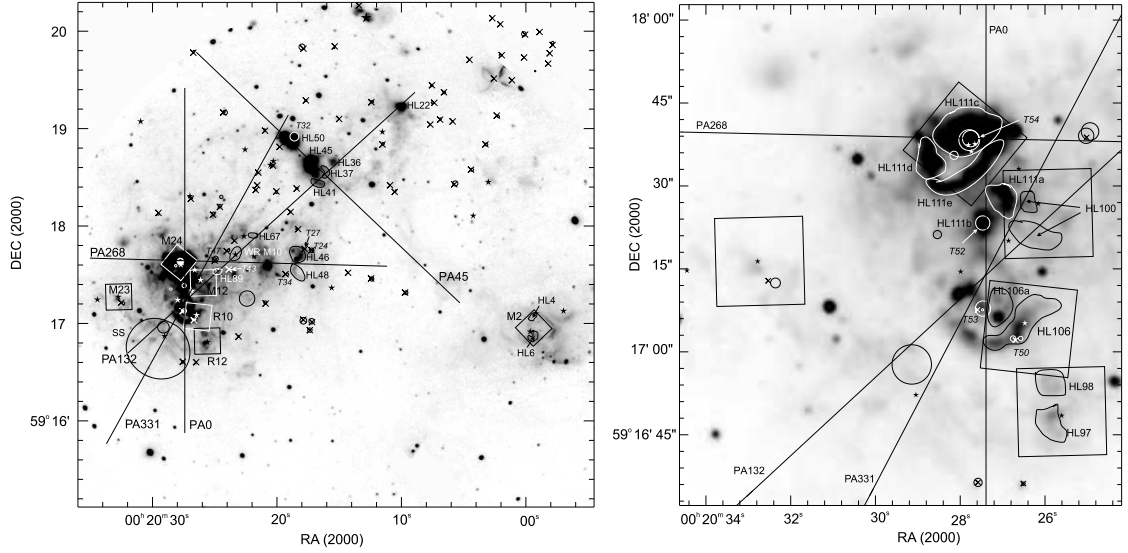


Fig. 2. Comparison of the results of our observations (open circles - Long Slit data, filled circles - MPFS data) and those of [5] (triangles) with the diagnostic diagrams $\log([\text{OIII}]/\text{H}\beta)$ vs $\log([\text{NII}]/\text{H}\alpha)$ and $\log([\text{SII}]/\text{H}\alpha)$ vs $\log([\text{OIII}]/\text{H}\beta)$ for models of [6] for $z=0.004$ and for different cluster masses and ages (solid and dashed lines correspond to $N_e = 10 \text{ cm}^{-3}$ and $N_e = 100 \text{ cm}^{-3}$), respectively.

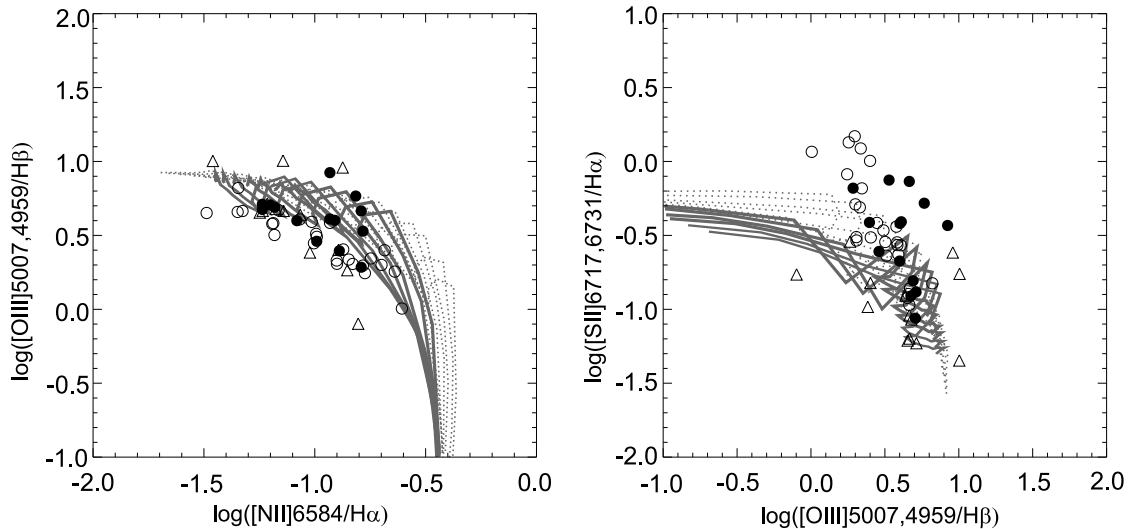


Table 2. Oxygen abundances estimated with MPFS and long-slit spectrograph.

HII-regions	$12 + \log(O/H)$
Observations with MPFS	
HL111c	8.16 ± 0.04
HL111d	8.17 ± 0.04
HL111e	8.23 ± 0.03
HL100	8.43 ± 0.04
HL111a	8.29 ± 0.05
HL106	8.36 ± 0.05
HL106a	8.31 ± 0.03
HL97	8.26 ± 0.06
HL98	8.35 ± 0.05
HL4	8.30 ± 0.16
HL6	8.18 ± 0.12
Observations with long-slit Spectrograph	
HL111a	8.33 ± 0.04
HL111b	8.41 ± 0.01
HL111c	8.18 ± 0.01
HL111d	8.26 ± 0.01
HL111e	8.29 ± 0.01
HL106	8.27 ± 0.05
SS	8.50 ± 0.09
HL37	8.15 ± 0.12
HL45	8.08 ± 0.01
HL50	8.18 ± 0.08
HL100	8.42 ± 0.02
HL89	8.44 ± 0.04
WR M10	8.42 ± 0.02
HL67	8.39 ± 0.04
HL41	8.38 ± 0.02
HL36	8.20 ± 0.02
HL22	8.38 ± 0.01
HL46-48	8.45 ± 0.01

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Fig. 3. Dependencies based on the data from Table 2b of the electronic version of the paper [6] for $N = 100 \text{ cm}^{-3}$ and metallicity $z=0.004$. Different curves correspond to different cluster masses (indicated in the units of $10^5 M_\odot$). The horizontal and vertical dashed lines show our observational data for the corresponding HII-regions.

